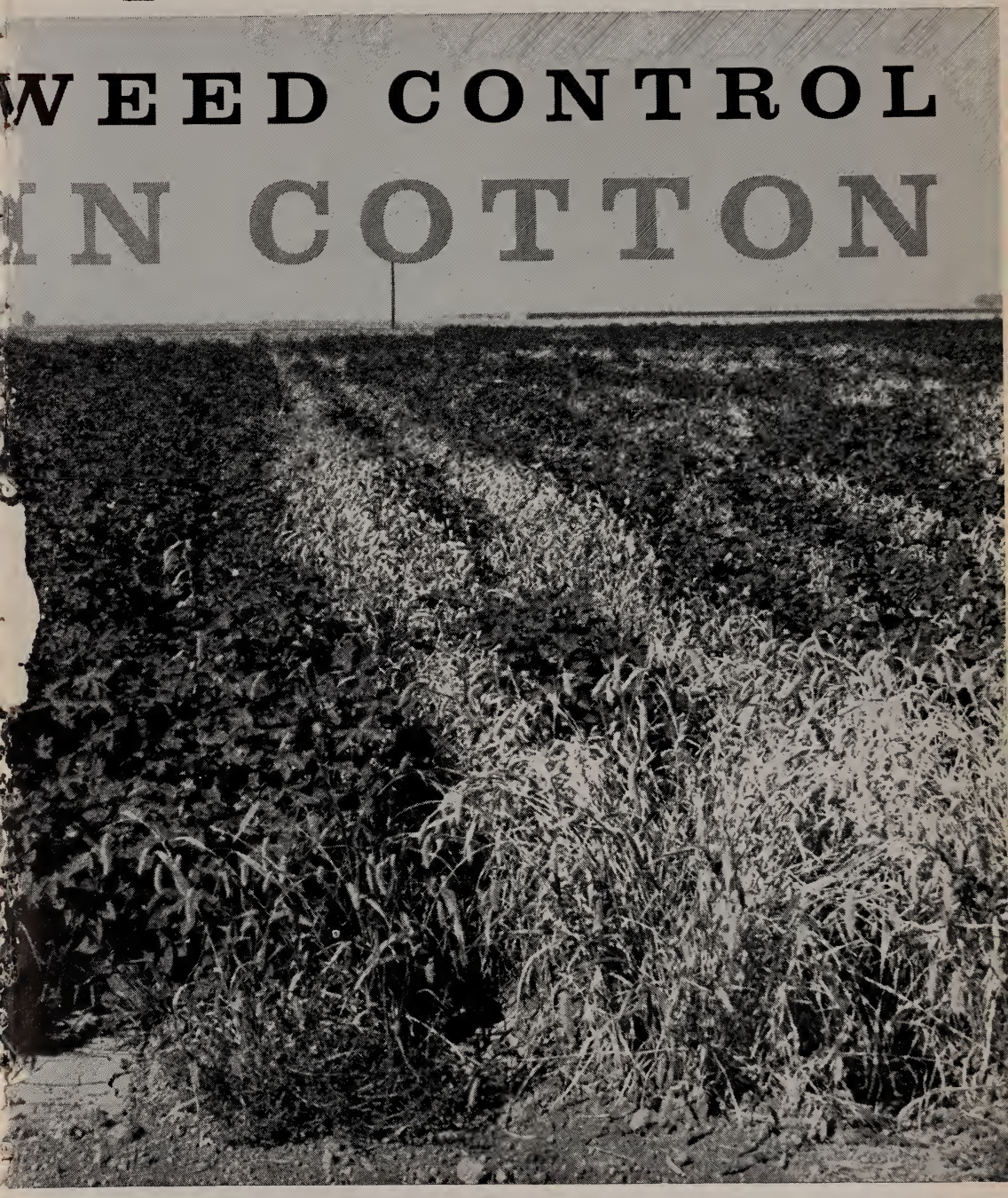
Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

WEED CONTROL IN COTTON



ILLER · FOY · KEMPEN · CARTER · HOOVER

CALIFORNIA AGRICULTURAL
EXPERIMENT STATION

BULLETIN 791

Annual grass in cotton at end of irrigation run.

THE PROBLEM

Cotton, California's leading cash crop, returns growers a total of approximately $300,000,000 annually from the state's 800,000 planted acres. Despite this, cotton has a serious production problem—that of weed control. Weeds reduce the value of the cotton crop from 4 to 6 per cent each year, and growers in the San Joaquin Valley report that they spend about $20 an acre yearly in attempting to control them.

Weed damage often is the result of several factors. Early weeds may compete with cotton for moisture, sunlight, and nutrients, thus lowering production and increasing hand-labor costs. Heavy

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THE COVER PHOTO was taken at the University of California's West Side Field Station, near Five Points. It shows test plots used in the study of the effectiveness of herbicides on cotton. Similar work is being carried on in other cotton-growing areas of the state by University and USDA scientists.

infestations of weeds late in the season may interfere with cotton defoliation, reduce the efficiency of both mechanical and hand pickers, and lower the grade of lint by introducing additional stains and trash.

It is estimated that over 90 per cent of California's cotton is now machine-harvested, as compared with about 10 per cent in 1948. During this same period, hand-labor requirements for cotton production were reduced by one-third, and present hand-labor requirements are largely for weeding. Thus, weed control is the principal barrier to complete mechanization of California's cotton crop.

While California cotton yields have been high, profits from them have not kept pace with increased production costs. Higher machinery costs and higher wages for hand labor have helped cause a tightening of profit margins. Further, the supply of farm workers can no longer be depended upon to handle California's cotton crop adequately, despite increased wages.

If California is to maintain its present high standing in cotton production it is imperative that sound, economical weed control practices be followed. Such practices include the best combination of cultural, biological, and chemical methods.

CULTURAL PRACTICES

Long term weed-control programs are advisable. Early elimination of small infestations, even at high cost, results in economy when considered over a long-term period. Consistent yearly efforts are essential in eliminating remnants of a weed population. Dangers of re-infestation from dormant seeds (such as field bindweed, or wild mustard), or from adjacent weedy areas, irrigation water, or grazing animals, must be considered before the eradication program is initiated.

Frequently, a community eradication program is justified, although full participation by all parties is required for success. After eradication of the selected weed species other species can be included in the control program until the entire problem is minimized or eliminated.

After analysis of the problem, a long term program can be started using any of the following methods of eliminating weeds: flooding, competitive cropping, hoeing, cultivation, burning, chemical control, fallow, systematic rotation—or various combinations of these.

Crop rotation

Good crop rotation is an important part of any well planned weed-control program. For cotton, the rotation should include crops whose growth habits, cultivation, and management interfere greatly with growth of troublesome weeds. Annual weeds are restricted, and often eliminated, by a rotation system which includes a small grain crop, such as barley, a cultivated crop, such as cotton, and a pasture or meadow crop. Certain other weeds are held in check by rotations which include smother crops, such as alfalfa.

The weed problem may also be lessened by practices which prevent weeds from reseeding, by a cultivation schedule that interferes with the normal development of most weeds, or by a selective chemical weed-control program for crops preceding cotton. When crops having similar growth habits are grown for successive years on the same field an environment favorable to at least one type of weed is established.

Definition of Terms Used

Layby: A term used to describe the time of the last cultivation. This time varies with growers, but is generally about mid-July in the San Joaquin Valley and mid-June in the desert valleys.

Carrot oils: Examples are Richfield Selective 1, Shell 10, Stoddard Solvent, Analos 7, Coberly & Plumb Herbicidal Oil 1.

Dirting: The act of moving soil into the plant row during cultivation, either to cover weeds or to build the bed profile for furrow irrigation.

By-pass agitation: A method of maintaining an emulsion or suspension of insoluble compounds by returning and recirculating a portion of the sprayer-pump output to the spray tank.

Irrigation run: Synonymous with the length of irrigation furrow.

psi: pounds per square inch (gauge).

LP: liquid petroleum.

Rhizomes: Underground stems of perennial weeds capable of regenerating new plants vegetatively. Also known as "rootstocks."

Proper selection of rotations often permits the maximum use of chemical aids in weed control. For example, 2,4-D may be used to control annual weeds in barley preceding cotton, whereas the reverse order of planting would be impossible. Also, diuron may be used both in cotton prior to cotton, corn or sorghum, and in alfalfa before cotton—but not in most other crop combinations, because of injurious residues left in the soil. Finally, flame cultivation is a satisfactory approach in cotton, but is out of the question in barley.

Land preparation and planting

The starting point for a weed-control program in cotton is land preparation. Proper land leveling eliminates low spots where water stands after each irrigation; this is important because water trapped in low areas of the field, or at the ends of irrigation "runs," provides excellent locations for the establishment of weeds. Irrigation systems which provide for efficient utilization of water accumulated at the end of the field will reduce weed problems.

Thorough incorporation of old plant residues into the soil is also important for efficient early weed control. Where large amounts of plant residue are present, shredding followed by efficient covering by plowing affords better seed-bed conditions and allows early effective cultivation.

Good planting practices result in more uniform emergence of cotton—a prerequisite to successful early cultivation. Good soil moisture and soil tilth are important considerations for uniform emergence. The uniformity of cotton emergence has also been markedly improved in recent years through use of the seed-firming wheel on planters, and better seedling disease control with fungicides. Where heavy rates of seeding are used, mechanical thinning of cotton will reduce the hoe-time required for early weeding and thinning.

Equipment adjustment

Use of accurately adjusted implements is highly advisable in such operations as bedding, planting, and cultivation, although the adjustment of equipment in the fields is often difficult and time-consuming because of irregularities in the soil surface. A line diagram similar to the one shown will aid materially in proper adjustment and requires only a smooth, level, surface marked with parallel lines representing the plant rows and the middles between the rows. Although other smooth surfaces will suffice, a concrete slab makes a permanent surface which can easily be marked with painted lines. For field rows 40 inches apart, parallel lines should be spaced 20 inches apart. The equipment can then be placed on the surface with the wheels centered exactly over lines representing the middles. The implement attachments to be used are then set as desired in relation to lines representing the plant rows. The line diagram should be large enough to handle multiple-row equipment. When implements are properly pre-set, only minor adjustments are necessary in the field.

Early cultivation

Mechanical cultivation is still the principal method of weed control used in western irrigated cotton. A variety of implement attachments can be used as supplements to normal sweep cultivation for early weed control. Research has shown that reversed disk hillers, bed knives, and rotary hoes, utilized individually or in combination, are effective tools for weed control early in the season when only limited amounts of soil may be moved. Only small seedling weeds may be killed easily; therefore, proper timing of the tillage operation is essential for effective control.

The above-mentioned operations may be begun as soon as sufficient cotton has emerged to enable the operator to follow the row. The rotary hoe attachment for

cultivation with the tines reversed has proved to be an effective shield for protecting small cotton. The rotary hoe holds the clods out of the cotton row, yet permits "dirting" (covering of small weeds with soil) of very small cotton plants. While most early-cultivating operations are rather slow and tedious, the use of the reversed rotary hoe permits cultivation of very small cotton at normal tractor speed. A rubber weeding tool that operates directly under the soil surface offers considerable promise as a device for removing seedling grass weeds in the cotton row. The rubber weeder should not be used on cotton less than about 2 inches tall, but must be used before the secondary root system of the weedy grasses has developed; this tool is best adapted to light soils. Many growers rely exclusively upon mechanical cultivation supplemented by hand hoeing for weed control throughout the season. When cotton plants have attained sufficient height to permit it, dirting with sweeps or other mechanical tools is one of the most com-

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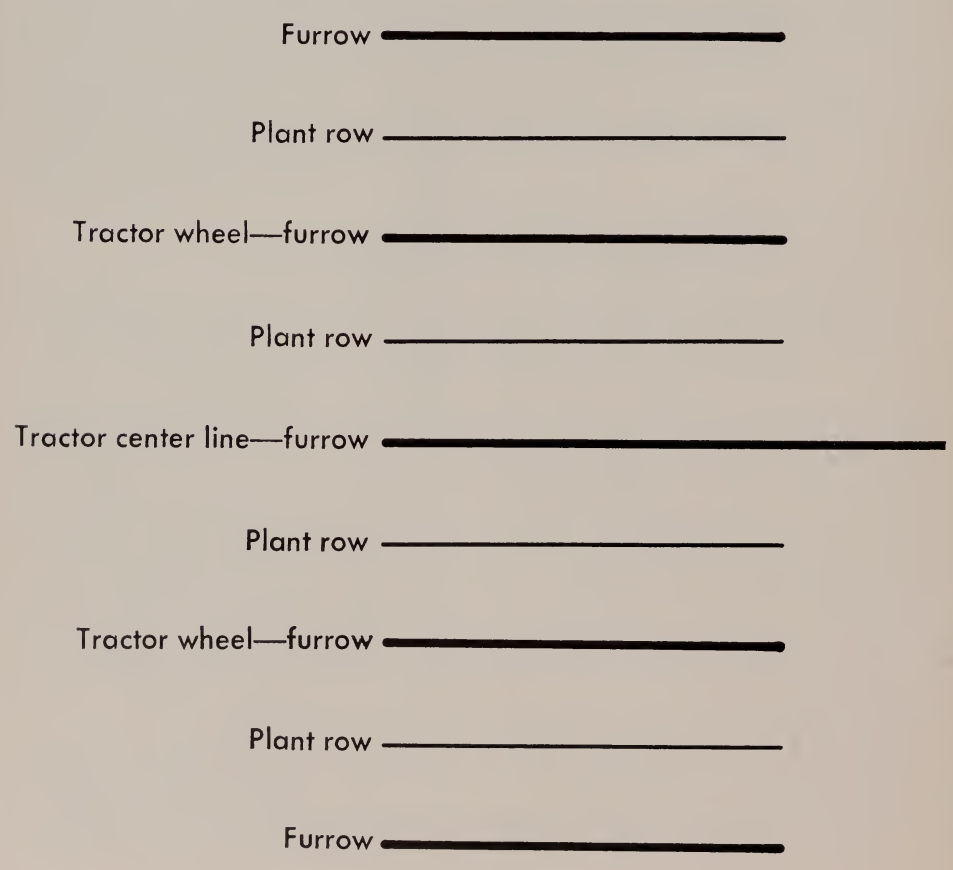
Below: the line diagram—a useful device for adjusting equipment. Distances between lines equal one-half of row spacing.



mon methods of weed control. If this is done, the bed profile should not be built up so high early in the season that dirting at "layby" is precluded.

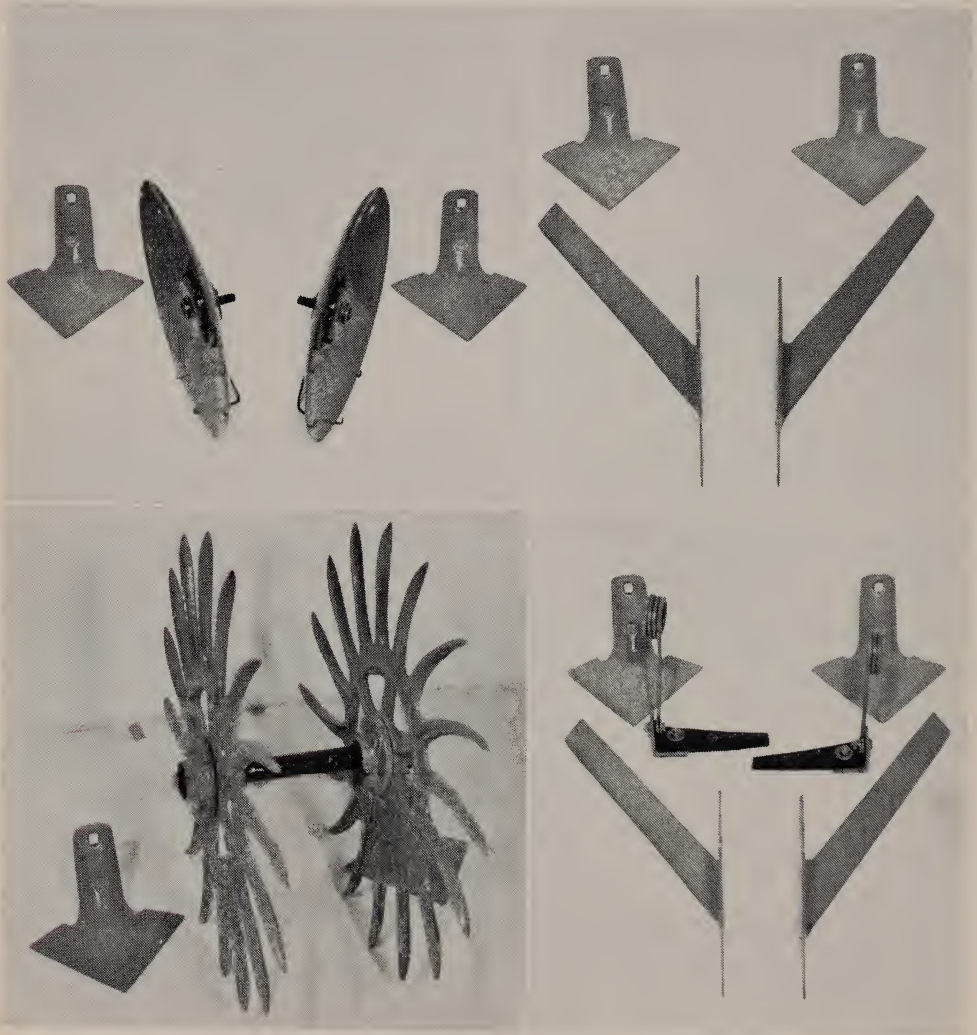
Combinations of cultivation tools for early weed control. Top left, reversed disk hillers (center) and sweep cultivating tools (left and right); Top right, sweep cultivating tools (top) and bed knives. Lower left, rotary hoe (center) and sweep cultivating tools; Lower right, sweep cultivating tools, rubber weeding tools (center), and bed knives.

Table 1. Effect of Date of Last Cultivation With High-Clearance Equipment on Cotton Yields and Picker Efficiency During 1951–1953 at Shafter, California

Last cultivation date	Yield of cotton	Picker efficiency
	bales per acre	*per cent*
August 1*	2.71	95.8
August 15	2.71	95.8
Sept. 1	2.66	95.1

* Check plots.

SOURCE: Tavernetti, James R., and H. F. Miller Jr., Studies on mechanization of cotton farming in California. University of California Exp. Sta. Bul. 747.



Late-season cultivation

California growers normally layby (cease cultivating) their cotton with a heavy dirting some time in July. Since cotton is usually irrigated after layby, late weed problems frequently develop.

Tests with high-clearance equipment (table 1) have indicated that with late-season cultivation a single 20″ to 24″ sweep in each furrow will provide weed control without injuring the cotton crop.

Cultivation should be shallow (not over 2″ deep) in order to minimize root pruning, and equipment must be shielded to prevent breaking of branches when traveling at normal tractor speeds.

HERBICIDAL OILS

Selective herbicidal oils have been successfully used for controlling seedling weeds in cotton 2 to 6 inches tall. These oils are specially formulated petroleum-naphthas containing no fortifying agent; they generally possess a boiling range of 300° to 400°F and a prescribed percentage of aromatic components ranging from 16 to 25 per cent. (Consult local agricultural authorities and oil manufacturers for further specifications and details of proper application.) When these oils are properly used they will kill small weeds without injuring cotton plants. At present, the only selective oils generally available in the western irrigated cotton areas are known as "carrot oils"; oils of higher boiling range and aromatic content do not exhibit the required selectivity.

Parallel-acting shoes with oiling nozzles attached.

Selective oiling is specialized: timing, stage of plant growth, rate of application, and spray placement, as well as the properties of the oil, are important in the selective action. For example, oils must be kept off the sensitive cotton terminals, and must not be used when cotton stems begin to crack and form bark. When oils can be used safely, they are applied as laterally-directed sprays at the rate of about 5 gallons per acre of cotton; application is confined to an 8 to 10-inch band centered on the row. Treatment may be repeated at weekly intervals as needed, but should not exceed three applications. Control of small emerging weeds will generally be excellent where proper care is exercised, although selective oiling will not control perennial weeds, or puncture vine more than 1 to 2 inches in diameter.

The biggest problem in oiling is preventing injury to the seedling cotton, but this can be avoided by using special application techniques. The first require-

ment is smooth, clod-free beds. Oiling operations have been more successful on relatively high-bed plantings, which permit establishment of irrigation furrows without moving soil (and additional weed seeds) into the oiled bands.

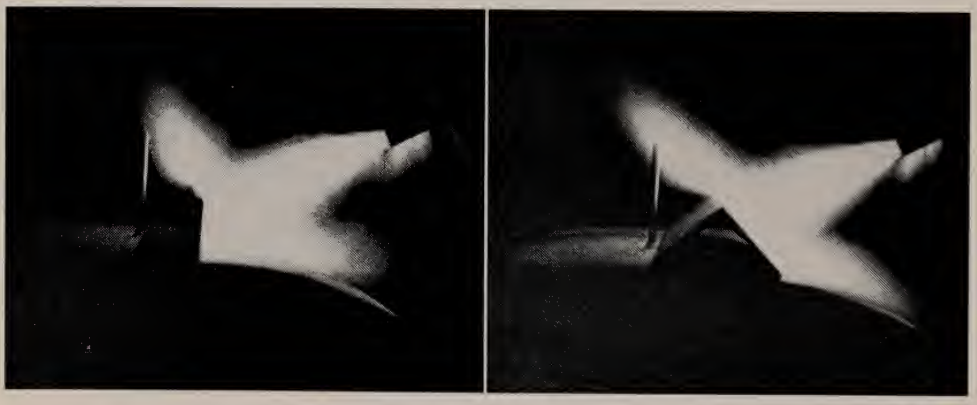
The use of special parallel-acting shoes with shields increases spraying precision and helps to hold soil out of the treated band. Since the two spray nozzles are mounted on the shoes, they follow the contour of the tops of the beds. Best distribution of spray is provided by flat, fan-type nozzles, mounted 1 inch above the bed and directed to the rear and at an angle of about 30 degrees to the row, with a spray pattern directed slightly downward so that the outer edge of the pattern strikes the soil 6 to 8 inches from the nozzle; the oil is applied to a band 8 to 10 inches wide centered on the plant row. This nozzle arrangement permits the overlapping of the spray patterns in the cotton row and has given satisfactory weed control with a minimum of crop injury. Nozzles should be set so that the spray fan strikes the young cotton stem no higher than 1 inch from ground level.

FLAME CULTIVATION

Principles and practice

Flame cultivation is often an effective supplement to mechanical and chemical weed control methods. Cotton, like most plants, will be killed by the heat intensity used in flame cultivation if it is in the seedling stage. Therefore, practical flame cultivation control of most weeds in cotton depends upon cotton being larger than the weeds. Destruction of weeds in cotton is also influenced by several variables, such as burner design, intensity and volume of the flame, length of exposure, and location of the burner with respect to the plant.

Flame cultivation, like directed oil sprays, eliminates weeds by contact. If viable seeds are present, successive populations of weeds will emerge after each irrigation, and repeated flame cultivations are necessary to control them.



Deflection of flame pattern caused by surface irregularities.

Although recent burner changes and improved application methods indicate that flaming may sometimes be started when cotton plants are only a few inches tall, initial flame treatments are normally applied with standard-size burners when cotton stems are approximately 3/16 inch in diameter at ground level; the plants are usually about 8 inches tall at this stage of development. With shielded, high-clearance tractors, flame cultivation can be continued until cotton bolls begin to open.

In general, flame should be used 3 to 6 days after an irrigation, and this often coincides with the time when furrows have dried enough to permit use of a tractor; most weeds emerging during an irrigation cycle do so during this period. For most effective use of flame, the weeds should not be over 2 inches tall.

Flame cultivation, which can be an integral part of a total weed control program, is used to control only the weeds in the cotton row. As with other weed control practices, uniformity in all field operations will determine the degree of success with flaming.

The row profile best suited to flame cultivation is smooth, free of depressions and ridges, and as free as possible of large clods. Laboratory and field observations have shown that row irregularities can cause flame to be deflected up into the cotton plant and cause plant injury; in addition, weeds behind ridges or in depressions will not be touched by the flame. When proper pre-flaming cultivations have left the row profile relatively smooth, flame cultivation has been found to be equally successful on high rounded, low rounded, or flat beds.

Two general systems of pre-flaming practices have been found to be compatible with flame cultivation in row-irrigated fields: (1) relatively high-bed planting with early weed control provided by application of directed oil sprays, and (2) relatively low-bed planting with moderate to heavy dirting to control weeds prior to the first flaming. When flaming follows directed oil applications, cultivation is normally limited to the furrow, leaving the bed undisturbed. When dirting is used as early-season weed control, it is essential that the final bed profile be developed before the first application of flame. Because soil probably contains weed seeds, none should be thrown to the plants after flaming starts.

Data obtained at many locations since 1945 have indicated that flame cultivation, with the adjustment described

Table 2. A 10-Year Summary of the Effects of Flame Cultivation on Yields of Cotton

Year	Date of first flaming	Number of flamings	Yield	
			Flame plots	Check plots
			bales per acre	*bales per acre*
1949	6/7	9	2.21	2.11
1950	7/8	3	2.56	2.63
1951	6/5	5	2.80	2.65
1952	6/13	6	2.19	2.13
1953	6/2	5	3.13	3.08
1954	6/3	5	2.66	2.66
1955	5/3	5	2.22	2.24
1956	6/5	6	2.16	2.17
1957	6/4	3	3.02	3.06
1958	6/3	3	2.46	2.50
Average	6/8	5	2.54	2.52

Table 3. Control of Barnyardgrass in Cotton With Flame Cultivation, and Effects on Grade of Cotton; 3-Year Summary

Treatment	Grass control*	Cotton grade after treatment	
		grade index†	grade reduction
Sweep cultivation (control plot)	1.8	91.0	1 grade
Flame cultivation	6.4	97.5	1/10 grade
Directed oil with flame cultivation	8.4	97.8	1/7 grade

* Grass control rating scale: 0 = no control; 10 = perfect control (grass free).
† Average grade index: 100 = middling; 94 = strict low middling; 85 = low middling.

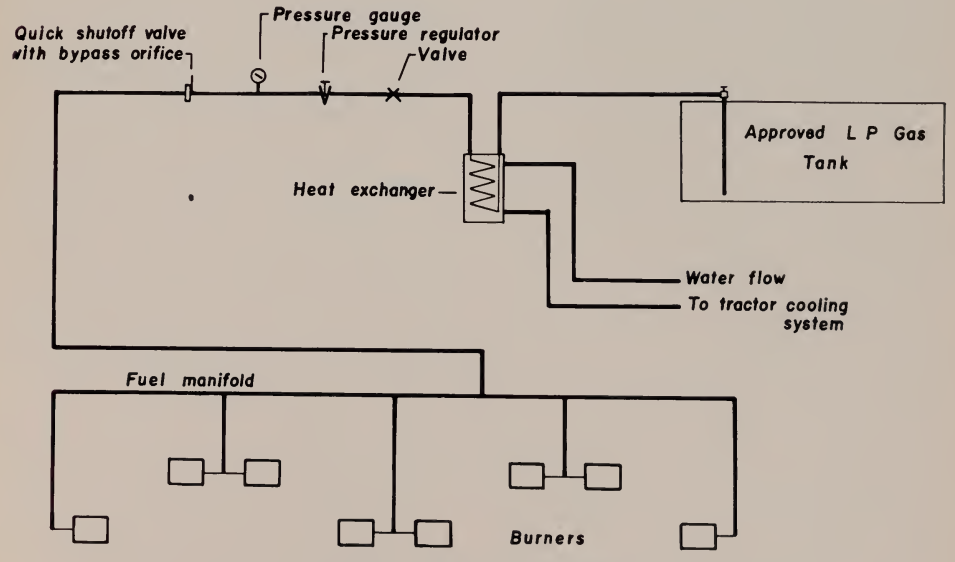
herein, will not damage the cotton stands or yields. Table 2 gives a 10-year summary of flame-cultivation test results under relatively weed-free conditions. There were no differences in yields between flamed plots and check plots when fields were flamed three to nine times during a growing season.

A 3-year test program designed to determine effectiveness of flame cultivation on annual-grass control and reduction of grass in the cotton bale showed it to be more effective than standard sweep cultivation. When an early application of directed oil spray was used with later flaming, a further increase in weed control was noted (table 3).

Flaming equipment

The components of a typical flame cultivator used in irrigated cotton are: a liquid petroleum (LP) tank, heat exchanger (fuel vaporizer), controls, fuel lines, and burners.

The fuel tank, all fittings, hoses, and tubing used in a flame cultivator must meet certain code specifications of the state and the American Society of Mechanical Engineers (A.S.M.E.) for handling butane and propane fuels. The fuel tank must be stamped with the state inspector's approval, and the safety valve should be in good operating condition at all times and should be repaired or replaced only by a competent serviceman.



Flame cultivator components.

Although the vapor valve is used at the top of the fuel tank to supply gas to burners in some 2-row cultivators, vaporization is not adequate for 4-row equipment. The normal practice is to withdraw liquid from the tank and vaporize it before it reaches the burner nozzles. Two systems of vaporization, known as vapor-burner and liquid-burner are commonly used. In the vapor-burner system, the liquid petroleum fuel is vaporized in a heat exchanger which utilizes the hot water of the tractor's cooling system. After vaporization, the gas is conducted through a pressure regulator to the manifold and then channelled to the individual burners. In the liquid-burner system, the liquid fuel passes through the pressure regulator and is vaporized in a heat-exchange chamber built into the burner.

In field comparisons of flame cultivators, no differences in weed killing could be found between the two systems of vaporization. During early flame cultivations, however, the vapor-burner systems have the advantage inasmuch as they can be quickly turned off when passing over areas where cotton is too small to withstand flame. The time elapsed in turning off the liquid-burner system is longer, as liquid in the lines must be vaporized and burned before the flame is extinguished.

Controls should be within easy reach of the tractor operator. A quick-opening valve with a small hole drilled in the gate will allow a pilot light to burn while the burners are shut off as the equipment turns at the ends of the field.

Flame burners are normally mounted solidly on the front or rear of cultivating equipment, and burner height is adjusted with the cultivator controls. Front mounting permits continuous visibility of the burner pattern and the cotton row during flaming. Rear mounting places the flame farther away from the tractor fuel tank and permits the tractor operator to drive away from the heat rather than into it. When operating in fields with uniform furrows on land leveled for irrigation, solid mounting to the cultivator permits precise vertical control of the burners, and also allows easy turning where ditches and furrows must be crossed. In certain areas of the Cotton Belt where cotton is planted without irrigation furrows, burners are frequently mounted on trailing skids which control the height of the burners and follow the land irregularities.

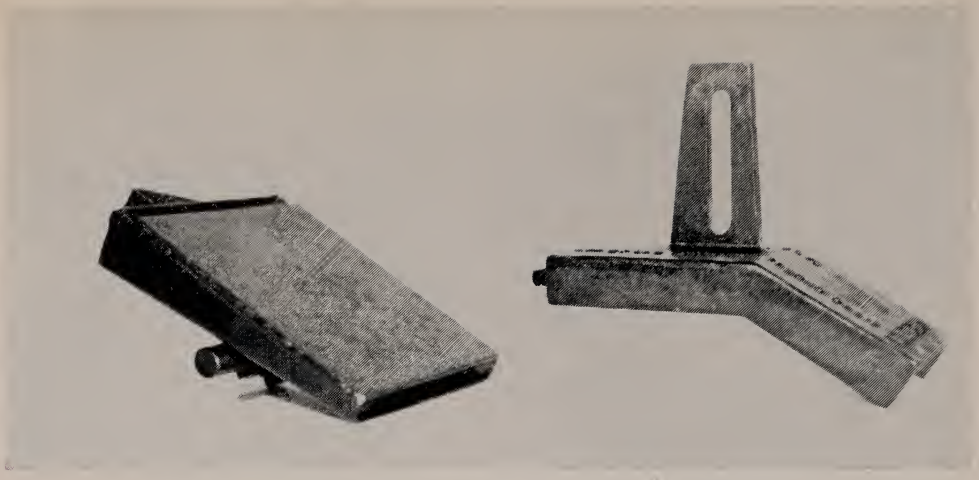
Flame-cultivator burners

Significant developments in burner design and positioning during the years 1948 to 1953 were largely responsible for revival of interest in flame cultivation in the mid-South and in California. The development of the flat Stoneville burner in Mississippi and its modifications in the Arkansas burner occurred during this period.

The flat Stoneville burner has a flame opening ½ inch by 5½ inches and uses a double orifice fan-spray nozzle for the fuel orifice. The Arkansas burner is a modification of this design, and incorporates a 30-degree deflector intended to minimize heat movement into the cotton.

The optimum position of the two burners has been determined through coordinated laboratory and field trials. The Stoneville burner should be set at an angle between 30 and 45 degrees from the horizontal. On smooth, well-formed beds, positioning the burner at the 30-degree burner angle will give better flame coverage over the bed. If beds are variable or rough, increasing the angle to approximately 45 degrees will cause less flame to be deflected into the cotton.

The Arkansas burner should be adjusted so that the combustion chamber is level. Then, because of its 30-degree flame deflector, its row coverage is identical with that of the Stoneville burner set at 30 degrees.

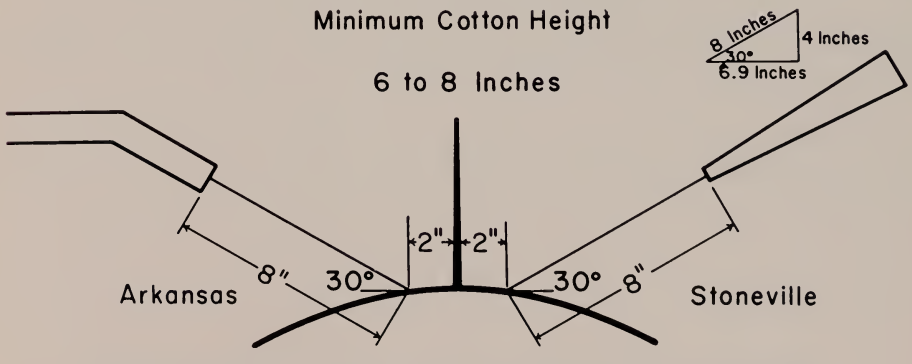


Flame cultivator burners. Stoneville burner (left) and Arkansas burner.

For normal flame cultivation a standard Spraying Systems T-Jet 2-2502 nozzle tip is used. This twin orifice, 25° angle, flat fan nozzle-tip delivers 0.20 gallons per minute at 40 psi and has been found to be the best for most conditions. When the 2-2502 nozzle tip is used, the distance from the tip of either type of burner to the point where the flame touches the bed should be 8 inches. In this position, the flame should strike the bed 2 inches on the burner side of the plant row. A steel rule laid along the top of the burner or deflector will aid in making these adjustments, as the accompanying drawing indicates. Either burner will vary slightly in its optimum setting, according to the shape and slope of the row.

The best setting for any burner-nozzle combination can be determined at night when the flame pattern is visible. The outlet end of the burners should be kept parallel to the row and level in order to insure uniform application of the flame, and the two burners, one on each side of the row, should be set in tandem so that flames will not oppose each other.

No differences in weed control or cotton plant damage are found between the two types of burners when operated with the same adjustments.



Proper adjustment of burners in relation to cotton plant and bed profile.

Tractor speed and fuel pressure

The speed of the flame-cultivator tractor is a critical factor if maximum weed killing and minimum cotton-plant damage are to be obtained. Tractor speeds less than 2¼ mph have resulted in moderate to severe damage to cotton plants, while speeds greater than 3½ mph have reduced the effectiveness of flame for killing weeds. The most satisfactory results have been obtained at speeds between 2¾ and 3¼ mph.

Within certain limits, the fuel pressure or rate of fuel consumption has less effect than tractor speed on damage to cotton. In general, as cotton height increases from 8 to 18 inches, fuel pressure may be increased from 35 to 50 psi for better weed control.

Cost of flame cultivation

Since fuel is the most costly single item in operating a flame cultivator, the cost of operation will vary with the price of LP gas, which in turn varies with quantity purchased and distance from source of supply. Cost of operation can be estimated by applying the local price of LP gas to the fuel consumption rates given in table 4 and adding tractor costs. Table 5 shows typical costs for mid-season flame cultivation.

Table 4. Fuel Consumption With Different-Sized Nozzle Tips Used at Various Pressures and Using Two Burners per 40″ Row.*

Orifice tip no.	Gallons per acre†			
	30 psi	*40 psi*	*50 psi*	*60 psi*
2–25015	2.50	3.18	3.65	4.26
2–2502‡	3.10	3.84	4.60	5.30
2–2503	4.66	5.73	6.76	7.75

* Fuel consumption for vapor burners with a tractor cooling system temperature of 180°F. For liquid burners, rates will be approximately 10 to 20 per cent less, depending upon construction of heat exchanger.
† No allowance made for turning.
‡ Recommended nozzle tip.
SOURCE: Carter, L. M., R. F. Colwick, and J. R. Tavernetti. 1960. Evaluating flame-burner design for weed control in cotton. Transactions of ASAE 3(2):125–28.

Table 5. Typical Costs of Mid-Season Flame Cultivation

Item	Amount per acre	Unit cost	Total cost per acre
		dollars	*dollars*
Fuel	4½ gal	0.12	0.54
Labor	¼ hour	1.25	0.31
Tractor	¼ hour	1.83*	0.46
		Total	1.31

* SOURCE: Reed, A. D. 1959. Machinery cost and related cost data. University of California Ext. Ser. (Mimeograph Report.)

Sound farming practices are essential to successful weed control, and herbicides for weed control should be considered as supplements to, rather than replacements for, such practices. Chemical weed control (if it can be used) offers a means of reducing labor costs in cotton production and may in some cases result in improved quality and/or increased yields.

Pre-emergence weed control

The weed control obtained in California with surface-applied pre-emergence herbicides in cotton has been erratic and unpredictable. To provide weed control, surface-applied herbicides must be water-borne from soil surface to the root zones of germinating weed seeds; rain, or sprinkler irrigation, is most effective for moving the herbicides, but furrow irrigation immediately after planting has not been successful.

Rainfall in cotton-producing areas of California is extremely unpredictable at the time of planting. Table 6 gives the probabilities of various amounts of rainfall from March 25 through April, at Madera, California (one of the cotton areas most likely to receive rainfall).

When rainfall of ½ inch or more occurred soon after herbicide application, certain herbicides controlled annual weeds satisfactorily. When rainfall was delayed, or did not occur after planting, pre-emergence herbicides failed to control annual weeds adequately.

Environmental conditions favorable to pre-emergence weed control in cotton are seldom found in California. The use of pre-emergence herbicides for annual weed control is thus limited to isolated areas where rainfall can be anticipated, or where sprinkler irrigation of ½ to 1 inch of water can be used. In these areas, pre-emergence herbicides may be applied as 10 to 12-inch bands over the drill row during or immediately after planting. The treated bands should be left undisturbed for maximum weed control. High-bed planting and planting to a stand (no thinning) will help to keep soil disturbance in the treated band to a minimum.

When rain has occurred, CIPC has generally proved to be the best pre-emergence herbicide used in California although it is not very effective for annual broad-leaved weeds. Cost of CIPC at rates of 6 to 8 pounds per acre, ap-

Table 6. Probability of Various Amounts of Rain in any Given Week During the Cotton-Planting Season at Madera, California (Based on a 34-Year Precipitation record)*

Rainfall	Probability of receiving stated amounts of rainfall				
	March	April			
	(4th wk.)	(1st wk.)	(2nd wk.)	(3rd wk.)	(4th wk.)
inches	*per cent*				
0.01+	21.2	16.2	9.0	6.1	16.3
0.1+	11.8	9.3	6.2	4.9	10.2
0.3+	8.2	5.7	3.2	1.6	5.7
0.5+	4.5	3.3	1.2	0.8	1.6

*Unpublished data.

plied in 10-inch bands, averages $3 to $4 per acre.

Evidence that certain compounds are herbicidally active when incorporated into moist soil suggests that spraying the surface and mixing the herbicide into the soil, or using subsurface applications of herbicides, may be a logical approach to early season weed control. Preliminary research data likewise indicate the possible advisability of applying herbicides before both pre-irrigation and planting. Should either of these practices prove effective, early weed control could be accomplished without reliance upon rainfall.

Early post-emergence weed control

There are no reliable chemical programs at present, except selective oiling, which provide weed control from the time of cotton emergence until a layby herbicide can be applied. Growers must rely upon mechanical means or upon directed oil applications until cultivation can be supplemented with flame.

Layby weed control

If cotton produces large amounts of foliage, cultivation alone or cultivation supplemented by flame may be adequate to protect it from weeds for the remainder of the season. However, cotton fields which have been relatively free of weeds until layby may present difficult weed problems by harvest time because of late weed emergence. This is especially true where the cotton stand is poor, or where vegetative growth is limited because of soil or other environmental conditions. In these cases, use of a herbicide immediately after the last cultivation can provide weed control for the remainder of the season.

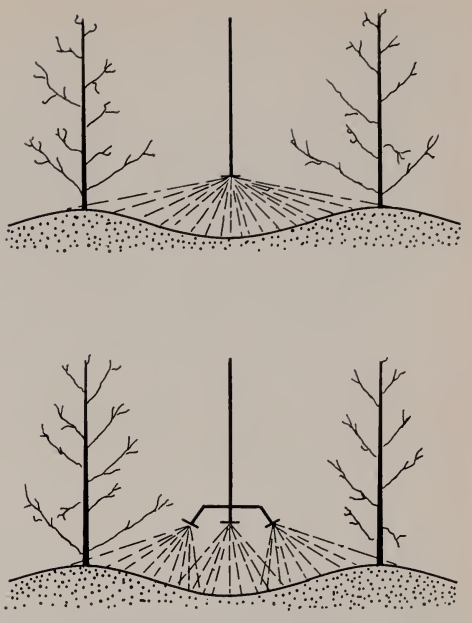
Layby herbicides generally must be applied before weeds emerge, and therefore the fields must be clean at time of application. Layby applications can be made with granular materials, or with broadcast-directed sprays in which the nozzle or nozzles are suspended midway between two rows of cotton. The spray pattern is adjusted to a height that will allow the pattern to overlap at the base

Herbicidal spraying at layby of cotton.

of the cotton plant and yet spray a minimum of herbicide on the cotton foliage.

Cotton plants are not injured when a few lower leaves are covered with the herbicide spray because these mature leaves manufacture little food for the plant after layby time, and thus their loss does not affect plant development. Shields or plant guards are advisable for partially lodged cotton, or for cotton which has heavily-fruited lower branches. The shields will permit more uniform coverage of the soil, and less herbicide will be wasted on cotoon foliage.

Layby herbicide applications should be followed by an irrigation soon after treatment. Control of the irrigation water to insure thorough wetting of the beds is essential to obtain successful weed control. Table 7 shows the results of a 4-year study of the influence of layby weed control with herbicides upon vigorous uniform stands of cotton at the U. S. Cotton Field Station at Shafter, California.



Arrangement of spraying nozzles between two rows of cotton.

Table 7. Layby Weed Control With Herbicides in Cotton (4 Year Period); U. S. Cotton Field Station, Shafter, California

Herbicide	Rate of application	Early layby weed rating*				Layby weed rating†			
		1955	1956	1957	1958	1955	1956	1957	1958
	pounds per acre								
Untreated	0.0	2.6	4.1	4.5	6.9	5.9	6.7	6.2	8.0
NPA	6.0	6.8	6.2	7.4	...	9.0	7.2	9.1	9.1
	9.0	6.6	5.7	7.7	...	9.1	7.5	8.0	8.4
CIPC	6.0	...	6.9	...	7.8	...	7.8	...	8.8
	9.0	...	7.4	7.5	8.4	...	8.3	6.7	9.0
Monuron	1.0	8.6	8.5	7.1	9.1	6.9	8.3	7.7	9.6
	1.5	8.5	8.9	8.3	8.8	7.4	9.0	8.9	9.5
Diuron	1.0	7.3	7.0	7.8	9.0	9.0	8.7	8.6	9.6
	1.5	8.8	8.0	8.6	9.1	9.1	8.0	9.4	9.6
CDAA	6.0	...	6.8	5.2	...	...	7.8	6.2	8.5
	9.0	...	7.4	4.6	...	...	7.9	7.3	8.6
Statistical analysis									
LSD .05		0.9	1.6	1.6	1 3	2.4	N.S.	1.8	1.0
LSD .01		1.2	2.0	2.2	1.8	N.S.	N.S.	2.4	N.S.

* Early layby: cotton 12–24″ in height; weed ratings: 0 = no control; 10 = complete control.
† Layby: cotton 24–48″ in height; weed ratings: 0 = no control; 10 = complete control.
Source: Miller, J. H., H. M. Kempen, J. A. Wilkerson, and C. L. Foy, Control of barnyardgrass (*Echinochloa crusgalli*) in western irrigated cotton. Weeds. 9(2):273–81.

Effect of different irrigations following herbicides applied at layby. (Top) Diuron applied at 1.6 pounds per acre, followed by standard irrigation. Note grass in drill row where water did not advance across top of bed. Foreground grass is dead. (Bottom) Diuron applied at same rate as above, followed by irrigation which completely wetted top of beds. Note absence of grass in drill row.

A comparison of herbicides applied at layby shows that the most effective weed control was obtained with diuron and monuron.* However, advantages of a herbicide application after cotton was 24 to 48 inches high were few because of the vigorous competitiveness of the cotton crop with late weeds. Where cotton stands are poorer, or where cotton growth is limited, advantages of layby herbicides are much more pronounced. In the latter instances, selective herbicides having residual activity (those that remain active in the soil for 2 months or more) have been most effective. Diuron and monuron fall into this class, whereas CIPC, which remains active in the soil for not over 4 to 6 weeks under these conditions, is intermediate. Thus diuron and monuron generally provide excellent weed control after a layby application.

* Diuron is registered for use in cotton in all of California; monuron is registered for use south of the Tehachapi Mountains only.

CIPC is effective on annual grasses but is relatively ineffective on broad-leaved weeds.

Diuron and monuron are wettable powders, and are only slightly soluble in water. Because of this, vigorous agitation must be maintained in the sprayer tank to keep the herbicides in suspension; mechanical agitation is more positive and is preferred to the bypass method of agitation. Both herbicides have a tendency to clog screens in the sprayer lines and screens smaller than 50 mesh should not be used.

Extreme caution should be exercised in calculating rates of herbicides. Proper calibration of spray equipment likewise cannot be over-emphasized (see "Appendix"). The suggested rates of application of monuron range from 1 to 1½ pounds per acre of 80 per cent material, depending upon soil; diuron should be used at rates of 1 to 2 pounds per acre of 80 per cent material. Diuron and monuron are adsorbed on the clay fraction of the soil, so that in soils containing large amounts of clay the higher rates quoted above are necessary for weed control. Neither of these herbicides is recommended for use on sands.

Because of the influence of soil properties on diuron and monuron, growers should at first try different rates of application on a limited acreage only. Where cotton cannot be followed by cotton, corn, or sorghum, CIPC may be used. CIPC should be used at the rate of 8 pounds per acre (on an active ingredient basis). The granular formulation provides more satisfactory weed control than the emulsified formulations. Water must be applied soon after the CIPC application.

Time of application. A layby application of monuron, diuron, or CIPC made during the last half of June will provide weed control for the remainder of the season without injury to cotton plants. Applications made at this time do not require high-clearance equipment, shields, or plant guards, and the number of sweep cultivations is reduced. In areas where there is difficulty with water penetration, however, fewer sweep applications may increase the problem.

Cotton plant injury may result if herbicides are applied too early, but usually results only when a large percentage of the total leaf area of the cotton plants is covered with spray. No cotton injury from directed spray has been encountered when plants were 12 inches tall, or higher.

The proper use of monuron, diuron, or CIPC has not reduced cotton yields and has improved grades of lint cotton materially, as compared to normally cultivated cotton where weeds are present—the improved grades have resulted from reduction of trash in the lint cotton. Cotton fiber qualities have not been altered by these herbicides.

Most annual broad-leaved and grass weeds are controlled by diuron or monuron; these include common morning-glory, rough pigweed, common lambsquarters, ground-cherry, purslane, barnyardgrass (watergrass), witchgrass, stinkgrass, and red sprangletop. Weeds not satisfactorily controlled include punctturevine, field bindweed (perennial morning-glory), established Johnsongrass and Bermudagrass, and nutsedge (nutgrass). CIPC will control annual grasses but is less effective on broad-leaved weeds.

Residual effects of layby herbicides. Layby applications of diuron and monuron may be active in the soil after the cotton crop is harvested, and all winter-planted crops and many spring-

For current recommendations and new developments in the use of selective herbicides in cotton and in other crops consult the latest "University of California Weed Control Recommendations," obtainable from your local Farm Advisor.

Because of the confusion often encountered in the use of common names, the Weed Society of America (WSA) has attempted to standardize terminology in the weed control field. Weeds and chemicals mentioned in this bulletin are listed below by their common and scientific names.

Weeds

WSA common name	Other common name(s)	Scientific name
field bindweed	wild morning-glory	*Convolvulus arvensis*
wild mustard	field mustard	*Brassica kaber* var. *pinnatifida*
puncturevine	bull head, goat head	*Tribulus terrestris*
common morning-glory	garden morning-glory	*Ipomoea purpurea*
pigweed	red root, careless weed	*Amaranthus retroflexus*
lambs-quarters	fat hen, white pigweed	*Chenopodium album*
ground cherry (not listed)	tomatillo	*Physalis ixocarpa*
common purslane	pussley, pursley	*Portulaca oleracea*
barnyardgrass	watergrass, cocksfoot	*Echinochloa crusgalli*
witchgrass	ticklegrass	*Panicum capillare*
stinkgrass	snakegrass, lovegrass	*Eragrostis cilianensis*
sprangletop (not listed)	scale grass, ray grass	*Leptochloa fascicularis*
Johnsongrass	Means grass	*Sorgum halepense*
Bermudagrass	devilgrass, wire grass	*Cynodon dactylon*
yellow nutsedge	yellow nutgrass, ground almond	*Cyperus esculentus*
Russian knapweed	Turkestan thistle	*Centaurea repens*
large crabgrass	hairy crabgrass	*Digitaria sanguinalis*
silverleaf night shade	white horsenettle	*Solanum elaeagnifolium*

Chemicals

WSA common name	Other common, commercial, or trade names	Chemical name
CIPC	Chloro IPC	isopropyl N-(3-chlorophenyl) carbamate
NPA	Alanap	N-1-naphthylphthalamic acid
CDAA	Randox	2-chloro-N,N-diallylacetamide
diuron	Karmex	3-(3,4-dichlorophenyl)-1,1-dimethylurea
monuron	Telvar	3-(p-chlorophenyl)-1,1-dimethylurea
TCA	Sodium TCA	trichloroacetic acid
dalapon	Dowpon	2,2-dichloropropionic acid
HCA	———	hexachloroacetone
SMDC	Vapam, VPM	sodium-methyl-dithiocarbamate
PBA	Benzac 354	polychlorobenzoic acid
2,3,6-TBA	Trysben 200, Benzac 1281	2,3,6-trichlorobenzoic acid
fenuron	Dybar	3-phenyl-1,1-dimethylurea
simazine	Simazine	2-chloro-4,6-bis (ethylamino)-s-triazine

planted ones *could* be injured by these residues. Therefore, only crops known to be tolerant to small amounts of diuron or monuron (such as cotton, corn, or sorghum) should be planted the season after a layby application of these materials; deep moldboard plowing after harvest will reduce toxicity of residues, but not sufficiently to permit safe cropping of nontolerant crops. CIPC will not remain in the soil to injure winter-planted crops, and chemical breakdown of soil-applied diuron or monuron is virtually complete in 12 to 15 months. No residual accumulation was detected over a 5-year period in which monuron and diuron were applied annually at layby time on a Hesperia fine sandy loam.

BIOLOGICAL METHODS OF WEED CONTROL

Geese have given excellent results in controlling grasses in cotton as they will feed on Johnsongrass, Bermudagrass, and nutsedge and seedlings of barnyardgrass, large crabgrass, witchgrass, and most other grasses, with little or no feeding on cotton or broad-leaved weeds. Geese should be present in the field from the time grasses emerge.

Several management problems must be considered when using geese. Clean drinking water must be available at all times but must be moved with regularity to train the birds to range; one or two drinking troughs in 20 acres filled daily should be sufficient. Supplemental feed must be used sparingly, as geese will not feed on grass if plentiful grain feeds are available. Pelleted feeds for poultry or rabbit are satisfactory and should be used at rates of about 10 to 20 pounds daily per 100 birds. Feeding areas should be moved regularly.

Old geese cannot be trained to feed on grass, and young goslings must be used each season. They should be at least 6 weeks of age and well-feathered before being placed in the fields.

Maintaining the proper balance between numbers of geese and weed populations is a major problem. If too few geese are used, they will be unable to control the growth of the weeds but too many geese for the weed population will require more supplemental feeding of the birds. Grass alone is not a well-balanced diet for geese and some deaths may occur because of compaction of the digestive tract. Normally, 3 to 5 geese per acre are sufficient to control most grass populations in cotton but after the first year the number can usually be reduced to 1 or 2 per acre; this number will vary with the density of the grass.

Shade must be provided for geese during the highest temperatures of the day during the warmest part of the season, and where natural shade is lacking cotton trailers are often used. Unless the shades are portable and are moved with regularity, the geese will damage cotton immediately adjacent to the shade.

Geese range more effectively during the cooler portions of the day, and are even more effective if allowed to range at night—although bird deaths due to predators is greatest then; dogs are by far the worst offenders in destroying geese. A 2 or 3-foot high 2-inch mesh poultry fence supported with light stakes or lath is generally used to confine young geese, but will not exclude predatory animals. Whenever they cannot be watched closely at night, geese should be protected. When toxic chemicals are used in the area, geese should be penned, as many chemicals are dangerous to the birds.

After the weeding season, the geese

can be sold or returned to the hatchery for credit. Most dealers contract to buy the mature geese for about 1 dollar per bird. Cost of weeding with geese will vary considerably from farm to farm. The number of geese, fencing, feed and water facilities, and extra labor are the major items. The following is an estimate of annual costs for a 40-acre field:

120 geese at $2 (less $1 credit for half of the geese)	$180
Wire and stakes $150 (pro-rated over 3 years)	$ 50
Grain	$ 60
Water and watering equipment	$ 80
Labor and incidentals	$150
Total	$520
Annual cost per acre	$ 13

CONTROL OF PERENNIAL WEEDS

Johnsongrass and Bermudagrass

Cultural methods. Dense stands of Johnsongrass or Bermudagrass in cotton cannot be economically controlled with herbicides at present, because the herbicides that control them also injure cotton. Where dense stands of such grasses occur, nonselective methods, such as summer fallowing or spraying with nonselective herbicides, should be used to reduce them.

Fallowing may be used to reduce grass population to scattered plants before herbicides are used as clean-up treatments in cotton. Following early-maturing crops, such as small grain or potatoes, the land may be fallowed for the remainder of the season. Cultivation with such equipment as the spring-tooth harrow after plowing will bring the rhizomes (see "Definition of Terms," page 4) to the surface of the soil, and exposure of the rhizomes to the hot, drying sun is an effective means of destroying much of the grass. Cultivations should be repeated at frequent intervals during the summer—for example, Johnsongrass growth should not exceed 12 inches between operations.

The use of nonselective herbicides as broadcast sprays may be advisable for isolated, densely populated patches of perennial grass in fields.

Soil sterilants. Winter applications of the sodium salt of trichloroacetic acid (TCA) at rates of 100 to 150 pounds per acre have in some cases almost eradicated perennial grasses. Rainfall, or irrigation, sufficient to carry the herbicide into the root zone of the grass is necessary, but too much water may carry the TCA below the root zone of the grass. Much TCA can be lost if exposed to high temperatures before rainfall or irrigation occurs and, in general, the rather exacting conditions necessary for good performance make it difficult to predict the effectiveness of TCA. Residues of this chemical in the soil may occasionally be toxic to spring crops following treatment, although tillage of the soil, and irrigation, will usually reduce residues to an insignificant amount. Flood irrigation is vastly superior to furrow irrigation for the removal of TCA.

Sodium chlorate may be used as a semi-permanent soil sterilant for the control of Johnsongrass and Bermudagrass. This herbicide is also dependent upon water to carry it into the root zone of the plant. The suggested rate, 1½ to 3 pounds per 100 square feet, will render the soil unproductive for 1 or more years, depending upon rainfall, or irrigation schedules. SODIUM CHLORATE IS A FIRE HAZARD IF COMBINED WITH FLAMMABLE MATERIALS SUCH AS CLOTHING OR PLANT RESIDUES

Table 8. Response of Johnsongrass and Yield of Seed Cotton as Influenced by Hand-Hoeing and Herbicidal Materials used as Four Spot Treatments in Two Locations, 1954

Treatment	Johnsongrass remaining after each application								Yield of seed cotton after treatments
	Kings County				Tulare County				
	Application				Application				
	1	2	3	4	1	2	3	4	
	percentage of original stand								*pounds per acre*
Hand-hoeing	55.6*	53.6	58.3	31.7	15.1*	11.4	6.8	3.5	1,454
Richfield Selective Oil 1	44.0	12.7	12.4	8.5	27.5	19.4	2.2	0.9	1,797
Shell Weed Killer 10	38.7	9.9	11.1	3.6	12.2	37.5	3.5	0.4	1,601
Cotton Weed Oil	44.0	8.3	17.4	6.3	21.3	41.0	8.2	0.2	1,633
Diesel oil	28.3	12.8	6.8	6.2	8.0	18.1	5.1	0.4	1,781
Diesel with HCA	27.1	17.4	16.6	10.0	10.3	26.4	3.1	0.2	1,535
Diesel-water emulsion with HCA	86.4	12.5	15.6	4.6	27.9	23.0	7.1	0.0	1,487
Dalapon, ¼ pound per gal	110.3	5.9	5.9	0.8	39.1	15.0	0.4	0.0	1,568
Dalapon, ½ pound per gal	45.4	3.9	5.9	0.5	13.6	11.8	0.8	0.0	1,650
Statistical analysis									
LSD .05	44.5	11.0	14.7	7.5	10.9	14.0	4.9	1.2	N.S.
LSD .01	N.S.	14.9	20.0	10.2	14.9	19.0	6.7	1.7	N.S.

* Wide differences between locations caused by removal of large numbers of rootstocks at first hoeing in Tulare County.

SOURCE: Miller, J. H., and C. L. Foy, The control of established Johnsongrass in cotton by spot treatment. Proc. South. Weed Conf. 8:104-09. 1955.

THAT HAVE BEEN WET WITH THE SPRAY—EXTREME CARE MUST BE EXERCISED IN THE USE OF THIS HERBICIDE. Sodium chlorate herbicides to which fire retardants have been added are available and are much safer to handle.

Spot-treatment in cotton. Dalapon at rates of 1/10 to 1/5 pounds per gallon of water may be used for spot-treatment of Johnsongrass or Bermudagrass. Because cotton sprayed with dalapon will be injured or killed, this type of treatment is suggested only where grass population is sparse. Hoeing the grass once early in the season before the spray program is started will increase difference in height between cotton and grass plants and reduce herbicide injury to cotton. Generally, two or three spray applications are necessary to give seasonal control and an application the second year will eliminate most remaining grass clumps.

Satisfactory control can be obtained without greater injury to the cotton plants than is experienced with hand hoeing. Table 8 shows control data collected from trials in which the original Johnsongrass population varied from 5 to 18 thousand plants per acre.

The applications may be made with tractor, knapsack, or gravity-flow sprayers. Low-pressure spraying should be used, as it prevents excessive fogging and drift of the herbicide. The perennial grass foliage should be thoroughly wet, but excessive runoff should be avoided.

To minimize cotton damage, dalapon should be applied whenever Johnsongrass growth reaches 8 inches in height. After application, cultivation should be delayed for several days. Removing top growth or disturbing the root system of the grass soon after treatment may reduce the translocation of the herbicide within grass plants. Marked effects of dalapon will not be seen until 1 to 2 weeks after treatment.

Herbicidal oils may also be used as spot-treatments for the control of perennial grasses in cotton and application is similar to that of dalapon. Oils are nonselective, and sprayed cotton will be injured. Generally, more frequent retreatment is required to control grasses with oils than with dalapon.

Broadcast foliar sprays. On areas not suitable for spot-treatment—roadsides, fence rows, ditch banks, or sizeable areas in crop land—control of perennial grasses can be obtained with broadcast foliage sprays containing dalapon. Such application will result in damage to the crop in the treated area. Dalapon is absorbed by the foliage and translocated to the underground roots and rhizomes, but under most conditions dalapon is broken down rapidly in the soil and does not sterilize soil for an extended period.

Results from dalapon are variable, depending upon weed growth and environmental conditions. In many of the trials, two applications of 15 to 20 pounds per acre eliminated most of the established perennial grasses. Best results are obtained when plants are treated first at the full vegetative stage of growth (18 to 24 inches tall) and then in late summer or fall; repeated applications in succeeding seasons are usually required.

For current recommendations and new developments in the use of selective herbicides in cotton and in other crops consult the latest "University of California Weed Control Recommendations," obtainable from your local Farm Advisor.

Broad-leaved perennial weeds

Infestations of most broad-leaved perennial weeds begin as isolated patches which, if uncontrolled, spread until they encompass the entire field. Soil sterilization or soil fumigation is the most re-

Control of Johnsongrass in cotton by dalapon spot-treatment (Left) Three spray applications of dalapon (one-fifth pound per gallon of water) on left; hand-hoeing on right. (Right) Injury symptoms in Johnsongrass after dalapon treatment.

liable method of controlling such patches of perennial weeds, and soil sterilants will keep the treated area free of vegetation for 1 or more years. Because treated areas will be unproductive, and also because of high cost, treatments should be limited to small spots. Although soil fumigation is costly, it allows normal cropping soon after treatment.

Spot-treatment with soil fumigants. Carbon disulfide has been used in California for more than 25 years. Usually, 2 ounces of the liquid is injected into holes 6 inches deep spaced 18 inches apart. Care must be exercised to insure sealing of the soil, either by rolling the soil surface or by flooding with water. The killing action of the chemical depends upon thorough penetration of its vapor into the root zone of the weed and, consequently, higher dosages are required for heavy or extremely wet soils. Applications made during periods of high temperatures or under windy conditions have not been satisfactory. Recently, equipment has been developed to apply carbon disulfide mechanically from a tractor-drawn subsoiler equipped with tank, pumps, and injector tubes. Carbon disulfide costs about $400 an acre to apply and is a potential health and fire hazard, but crops may be safely planted 3 to 4 weeks after treatment with it.

Sodium - methyl - dithiocarbamate (SMDC) can be used at rates of 75 to 100 gallons per acre injected into the soil or applied in irrigation water. Since the soil must usually be irrigated to be moist enough for the injection method of application, application of the herbicide in irrigation water is frequently the more practical method. Amounts of herbicide toxic to crops may remain in the soil for 1 to 3 months. SMDC is very irritating to skin, eyes, and mucous membranes, and care should be taken in handling to avoid inhaling it or getting it on skin and eyes.

Methyl bromide at 2 pounds per 100 square feet of soil surface is effective for killing isolated infestations of perennial weeds. The soil surface must be covered with a gas-proof covering before the methyl bromide is used, since it volatilizes to a gas. The covering may be removed 24 hours after application.

Before application, soil should be made loose and friable, and should be moist but not wet. The area treated should extend 10 to 12 feet beyond the area known to be infested with the weed; this insures

against regrowth from roots or rhizomes extending beyond the known infestation area. Crops may be safely planted in areas treated with methyl bromide as soon as the gas has escaped (2 to 3 days after application).

Methyl bromide is very poisonous. *Attention to directions printed on the herbicide container is essential.*

Spot-treatment with soil sterilants. Sodium chlorate has been used in California for over 30 years. Experience has shown that rates for eradication of perennial weeds are very dependent upon soil characteristics, rainfall, and species of weed being treated. For broad-leaved perennial weeds, 3 pounds per 100 square feet should be used, and results are improved if treated areas are flooded with 3 to 6 inches of water immediately after application; used at the above rate, sodium chlorate costs approximately $200 an acre. (*Note: sodium chlorate is a fire hazard unless it contains a fire retardant.*)

The **chlorate-borate** mixtures are equally costly, but generally are more popular than sodium chlorate because they are less hazardous; suggested dosages range from 4 to 6 pounds per 100 square feet. As with sodium chlorate, irrigating with 3 to 6 inches of water (unless rain is expected soon after application) has generally improved the kill of perennial broad-leaved weeds.

Monuron, a more recent herbicide, is widely accepted for control of perennial weeds, and applications of 40 pounds per acre are generally successful. However, in many cases weed kill is rather slow—particularly if supplemental water is not used. Since monuron is subject to photodecomposition and is relatively insoluble, the desirability of an irrigation after herbicide application is increased in areas of low rainfall. Monuron is relatively inexpensive as compared with most other commonly used soil sterilants, costing approximately $120 an acre, and is safe to handle—but it has the disadvantage of having a long residual life in the soil. A survey of plots treated in Fresno County showed that most treatments applied as long ago as 5 years still prevented normal growth of crops.

The **chlorinated benzoic acid herbicides (PBA and 2,3,6-TBA)** are relatively new, and data regarding their performance on perennial weeds are still rather limited. Yet, evidence indicates that both the polychlorinated and trichlorinated benzoic acid herbicides show considerable promise on such deep-rooted perennial weeds as field bindweed and Russian knapweed. Suggested rates for perennial weed control are 40 and 20 pounds per acre (acid equivalent) respectively, with costs being about $100 per acre for either treatment. Data on persistence of these herbicides in soils are limited, but either of the benzoics will usually render the soil unproductive for one or more seasons. Breakdown in soils is slow, but the chemicals appear to be leached from soils when flooded; generally, over 30 inches of water are required. Grass crops (corn, sorghum, or grains) are injured less by residual amounts of the benzoics than are broad-leaved crops (cotton, beans, or alfalfa). Although grass crops may grow and produce a partial or total crop of grain on benzoic-treated soil, *such grains may contain chemical residues in excess of those set by the Federal Food and Drug Act, and therefore the crop should not be harvested.*

Fenuron at 40 pounds per acre gives results comparable to monuron for perennial weed control. Fenuron may give more satisfactory results over a wider range of conditions in arid areas, as it is about ten times as soluble as monuron.

Simazine at 20 pounds per acre (active ingredient) will effectively eliminate Russian knapweed at an estimated cost of $110 per acre. This is a herbicide which requires much moisture to activate it, and which, because of its insoluble nature, will persist in the soil for long

periods of time. Certain crops, such as corn, have high tolerance to simazine and can be grown on soil containing quantities toxic to many other crop plants.

The **chlorate-borate-monuron** and **borate-monuron** combinations applied at rates of 2 to 3 pounds per 100 square feet will also eliminate perennial broad-leaved weeds. These herbicides provide control of seedling weeds longer than do borate-chlorate herbicides. Data available regarding their persistence in the soil are limited, but residual properties are probably similar to those of monuron.

Cultural control. The herbicide treatments described for the control of broad-leaved perennial weeds are suggested only for small infestations. Large infestations should be controlled by other methods, such as tillage.

The principle involved with tillage is starvation of the plant, and this principle applies to both perennial broad-leaved and grass weeds. The food reserves stored in roots or rhizomes of perennial weeds can be depleted most rapidly by allowing the plants to emerge and grow for about 2 weeks (but never more than 3 weeks) before each tillage operation. Perennial weeds will generally use stored foods from the roots during the first 2 weeks of growth, but after that they begin to manufacture foods in the leaves and to translocate food material to the roots for storage. If eradication is to be accomplished, therefore, the tillage operations must be performed on schedule consistently for two or more growing seasons. The use of a sweep cultivator (duckfoot type), rather than a disk or spring-tooth harrow, will result in a more complete job of shearing off perennial broad-leaved weeds.

PRECAUTIONS IN USING HERBICIDES

Read the Label

Reasonably safe herbicides may be hazardous if carelessly handled. Follow all precautions for safe, legal, handling found printed on the manufacturer's label. Recommendations made in this bulletin and in "University of California Weed Control Recommendations" comply with state and federal laws regarding the use of herbicides. To avoid crop injury and excessive residues on the harvested crop, follow directions carefully with respect to dosage levels, number of applications, and minimum intervals between applications and harvest.

Go Slowly

Do not attempt to use chemical weed control methods on a large scale until thoroughly familiar with the chemicals, the correct methods of application, and their side effects. Treat only a small portion of total acreage the first year and increase the acreage treated as you gain experience in chemical weed control methods.

Hazardous Chemicals

2,4-D and related compounds are hazardous compounds insofar as cotton is concerned. Extreme care is required to avoid injury from spray drift, vapor drift, or dust particles containing the herbicide. In general, cotton should not be treated with a sprayer used for 2,4-D and related chemicals.

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APPENDIX

Sprayer calibration

All sprayers should be carefully calibrated before use. Recalibrations should be made periodically to assure that pumps or nozzles have not been worn or that other changes have not occurred.

The basic step in any calibration procedure is the selection of nozzle tips. Check the manufacturer's handbook and determine tractor speed for the gear in which the tractor is to be operated. Then, from the nozzle-manufacturer's charts, select the tip that will deliver closest to desired output to match speed and pressure used. Modifications of two general methods of sprayer calibration are presented below.

Method 1.

Procedure:

1. Determine the exact speed of the tractor by timing it over a measured course and mark the throttle setting. (Example: 264 feet = $\frac{1}{20}$ mile; therefore, $\text{MPH} = \frac{180}{\text{Sec. to go 264 feet.}}$)
2. Start with a full tank of clean water.
3. Determine the number of gallons used in 6 minutes by one of the following methods (use a stop watch or a watch with a second hand to time the 6 minutes and measure the water to the nearest pint):
   a) Place a bucket under each nozzle and measure the total amount of water sprayed in 6 minutes, or
   b) Measure the amount of water required to refill tank after the 6-minute run.
4. Calculate spray coverage in inches. (See "Notes on calibration," next page.)
5. Substitute this information in the following formula*:

$$\text{Gallons per acre} = \frac{1000 \times \text{gallons used in 6 minutes}}{\text{width of spray coverage in inches} \times \text{miles per hour.}}$$

6. If this is more than the amount desired, decrease pressure; if less, increase pressure and recalibrate.

Method 2.

Procedure:

1. Start with a full tank of clean water.
2. Operate for $\frac{1}{4}$ mile (1320 feet) with the determined pressure and with the tractor throttle in the marked operating position.
3. Refill tank and convert the amount to gallons and fractions of gallons (nearest pint).
4. Calculate spray coverage in inches. (See "Notes on calibration," next page.)
5. Substitute this information in the following formula†:

$$\text{Gallons per acre} = \frac{400 \times \text{gallons used in } \frac{1}{4} \text{ mile}}{\text{width of spray coverage in inches.}}$$

6. If this figure is more than the amount desired, decrease pressure; if less, increase pressure and recalibrate.

* Accurate to 1%. If greater accuracy is desired, substitute the factor 990 for the factor 1000 in this formula.

† Accurate to 1%. If greater accuracy is desired, substitute the factor 396 for the factor 400 in this formula.

Notes on calibration

1. Boom lines must be filled before beginning.
2. Nozzles must be delivering uniform amounts (within 10 per cent).
3. Speed or pressure must not be changed during course of the calibration.
4. Accurate measurement of the amount of water sprayed is essential. Tank should be level when refilling to the pre-determined mark. Error should be less than 10 per cent in duplicate trials.
5. The width of spray coverage for band application is the sum of the band widths; for 10-inch bands and a 4-row spray boom the spray coverage is 40 inches. In broadcast application the spray width is the effective boom coverage—for example, for 40-inch rows and 4-row spray coverage the width is 160 inches.

Use the following method to determine the amount of herbicide to be put in the sprayer tank:

1. To obtain the number of acres one filling will spray, divide the number of gallons the tank will hold by number of gallons applied per acre.
2. To obtain the amount to be used per tank, multiply number of acres the tank will spray by the amount of herbicide to be used per acre.

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